The Reaction $pp \to pp\phi$ and the Validity of the OZI Rule *

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Abstract

The reaction $pp \to pp\phi$ is investigated within a relativistic meson-exchange model of hadronic interactions. The possibility of extracting the $NN\phi$ coupling constant from a study of this process is explored. A combined analysis of $\omega-$ and ϕ-meson production in proton-proton collisions utilizing recent data on these reactions is carried out and yields values for $g_{NN\phi}$ that are compatible with the OZI rule.

1 Introduction

Recent experiments on $\bar{p}p$ annihilation at rest revealed unexpectedly large cross section ratios $\sigma_{\bar{p}p\to\phi X}/\sigma_{\bar{p}p\to\omega X}$, exceeding the estimate from the OZI rule by one order of magnitude or even more (cf. Ref.[1] for a compilation of data). These large ϕ-production cross sections were interpreted by some authors as a clear signal for an intrinsic $\bar{s}s$ component in the nucleon[1].

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However, in an alternative approach based on two-step processes these data can be explained without introducing any strangeness in the nucleon and any explicit violation of the OZI rule[2].

In this context ϕ production in nucleon-nucleon collisions is of specific interest. Here one does not expect any significant contributions from competing OZI-allowed two-step mechanisms. Therefore cross section ratios $\sigma_{pp\rightarrow pp\phi}/\sigma_{pp\rightarrow pp\omega}$ should provide a clear indication for a possible OZI violation and the amount of hidden strangeness in the nucleon. Indeed preliminary data presented recently by the DISTO collaboration indicate that this ratio is about 8 times larger than the OZI estimate[3].

In this work we report on a model analysis of the DISTO data with the aim of extracting the $NN\phi$ coupling constant. Specifically we want to see whether the observed enhancement over the OZI estimate in the cross section implies a $g_{NN\phi}$ that is likewise enhanced and therefore at variance with the OZI rule.

2   The Model

We describe the $pp \rightarrow pp\phi$ reaction within a relativistic meson-exchange model, where the transition amplitude is calculated in Distorted Wave Born Approximation in order to take the NN final state interaction into account. (See Ref.[4] for the details of the formalism.) For the NN interaction we employ the model Bonn B[5]. We do not consider the initial state interaction explicitly. Its effect is accounted for via an appropriate adjustment of the (phenomenological) form factors at the hadronic vertices.

In a previous study of the reaction $pp \rightarrow pp\omega$[4] we found that the dominant production mechanisms are the nucleonic and $\omega\rho\pi$ mesonic currents, as depicted in Fig. 1. We also found that the angular distribution of the produced ω meson provides a unique and clear signature of the magnitude of these currents, thus allowing one to disentangle these two reaction mechanisms. The situation is quite similar for the reaction $pp \rightarrow pp\phi$. In this case the nucleonic current and the $\phi\rho\pi$-exchange current provide the dominant contributions to the production amplitude[6]. Therefore, it is possible to fix uniquely the magnitudes of the nucleonic and the meson-exchange current by analyzing the angular distribution of the ϕ meson measured by the DISTO collaboration[3]. Furthermore, since the $NN\phi$ coupling constant enters only in the nucleonic current it is possible to extract its value from such an anal-

ysis. It is determined by the requirement of getting the proper contribution of the nucleonic current needed to reproduce the angular distributions.
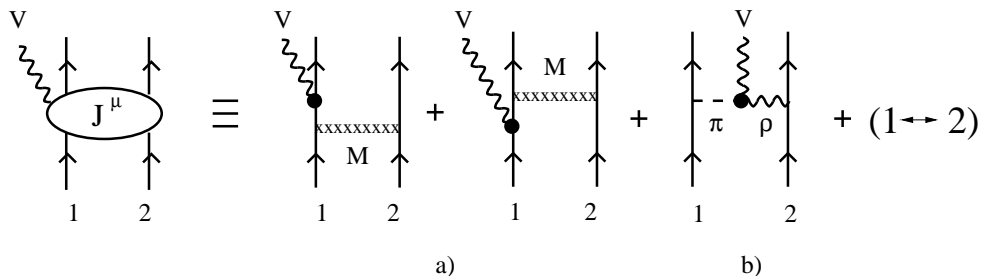

Figure 1: ω and ϕ meson production mechanisms: a) nucleonic current; b) $V\rho\pi$ meson-exchange current.

The parameters of the model (coupling constants, cutoff masses of the vertex form factors) are mostly taken over from the employed NN model. The $\phi\rho\pi$ coupling constant is obtained from the measured decay width of $\phi \to \rho + \pi$. However, besides the $g_{NN\phi}$ that we want to extract from the analysis, there are still some more free parameters: The cutoff mass of the $\phi\rho\pi$ vertex form factor of the meson-exchange current, and the form factor and tensor- to vector coupling constant ratio $\kappa_\phi \equiv f_{NN\phi}/g_{NN\phi}$ of the nucleonic current (cf. Ref.[6] for details). Thus in order to determine these remaining four parameters we need at least four independent ϕ-meson production data. In view of the more limited data set presently available, we decided to perform a combined analysis of ϕ- and ω-meson production. This means that we use the data from both reactions and we assume relations between corresponding parameters in the production amplitudes. Specifically, we assume that the form factors at the $\phi\rho\pi$- and $\omega\rho\pi$ vertices are the same. This is a reasonable choice because the off-shell particles (ρ, π) are the same in both cases. Likewise we assume that the form factor at the meson production vertices in the nucleonic current are the same. The $NN\omega$ coupling constant is fixed to the SU(3) value, $g_{NN\omega} = 9$, based on $g_{NN\rho}$ of Ref.[7]. Furthermore we assume that $\kappa_\phi = \kappa_\omega$, as also suggested by SU(3) symmetry, and $-0.5 \leq \kappa_\omega \leq 0.5$.

Concerning the data we use the total cross sections of Ref.[8] for the reaction $pp \to pp\omega$ and the ϕ-meson angular distribution at $T_{lab} = 2.85$ GeV measured by the DISTO collaboration[3]. The latter is given without absolute normalization in Ref.[3]. But since the DISTO group has also measured

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the ratio $\sigma_{pp \to pp\phi}/\sigma_{pp \to pp\omega}$ at this energy we can estimate $\sigma_{pp \to pp\phi}$ by multiplying this ratio with the total cross section for ω-meson production interpolated from the existing data. This yields a value of $\sigma_{pp \to pp\phi} \approx 0.3 \ \mu b$.

3   Results and Discussion

After the above considerations, we are now prepared to apply the model to the reactions $pp \to pp\omega$ and $pp \to pp\phi$. The angular distribution for ϕ-meson production measured at $T_{lab} = 2.85$ GeV is shown in Fig. 2. We observe that the angular distribution is fairly flat. Recalling the results we obtained for ω production[4] this tells us that ϕ-meson production should be almost entirely due to the $\phi\rho\pi$ meson-exchange current. Only a very small contribution of the nucleonic current is required if the angular distribution drops at forward and backward angles, as indicated by the data.
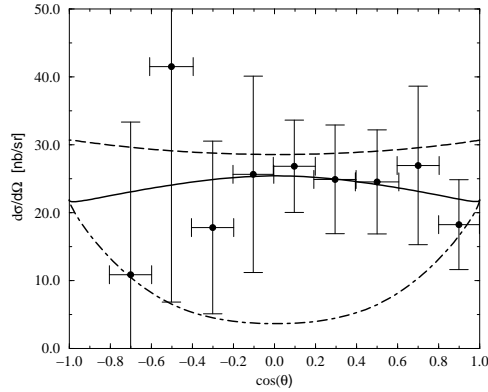

Figure 2: Angular distribution of the ϕ meson at $T_{lab} = 2.85$ GeV. The dashed (dash-dotted) curve is the result with the mesonic (nucleonic) current alone. The solid curve is the total result. The data points are from Ref.[3], normalized as discussed in the text.

Our strategy for fixing the various parameters is outlined in detail in Ref.[6]. Here we only want to mention that the lack of a more complete set of data prevents us from achieving a unique determination of $g_{NN\phi}$. Rather we get a set of values which range from $g_{NN\phi} = -0.163$ to $g_{NN\phi} = -1.40$.

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Nevertheless, it is encouraging to see that the extracted values all lie within fairly narrow bounds. This clearly indicates to us that the dependence on the model parameters is not very strong, and that the magnitude of $g_{NN\phi}$ is primarily determined by the experimental information used.

The values of $g_{NN\phi}$ obtained may be compared with those resulting from SU(3) flavor symmetry considerations and imposition of the OZI rule,

$$g_{NN\phi} = -3g_{NN\rho}\sin(\alpha_v) \cong -(0.60 \pm 0.15) ,$$

where the factor $\sin(\alpha_v)$ is due to the deviation from the ideal $\omega - \phi$ mixing. The numerical value is obtained using the values of $g_{NN\rho} = 2.63 - 3.36$[7] and $\alpha_v \cong 3.8^o$. Comparing this value with the ones extracted from our model analysis, we conclude that the preliminary data presently available can be described with using a $NN\phi$ coupling constant that is compatible with the OZI rule. This clearly indicates that a dynamical model is needed for drawing any conclusion about the validity of the OZI rule.

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